Multicriterial Assessment of RES- and Energy-Efficiency Promoting Policy Mixes for Russian Federation

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Abstract. We focus on assessing RES- and energy-efficiency promoting policy mixes for Russia from multicriteria perspective with emphasis on GHG emission reduction. We start from two surveys: the first one studies country's energy saving and RES potential to determine possible range of outcomes for policy mixes in question; the second one reviews corpus of relevant official documents to formulate policy alternatives, which the policymakers are facing. Our findings are then blended with forecasts of government and international agencies to obtain three scenarios, describing possible joint paths of development for Russian energy sector in the context of demographic, economic and climatic trends, as well as regulatory impact from three policy portfolios, for period from 2010 (baseline year) till 2050. Scenarios are modeled in Long-Range Energy Alternatives Planning (LEAP) environment, and the output in the form of GHG emissions projections for 2010–2050 is obtained. We then assess three policy portfolios with multi-criteria climate change policies evaluation method AMS. Our analysis suggests that optimistic scenario is most environmentally friendly, pessimistic one is easier to implement, and business-as-usual balances interests of all stakeholders in charge. This might be interpreted as an evidence of lack of governmental regulation and motivation to intervene in energy sector to make it greener and more sustainable. Research was done with support of grant under European Union FP7 program PROMITHEAS-4 "Knowledge transfer and research needs for preparing mitigation/adaptation policy portfolios".

Аннотация. В данной статье методы многокритериального принятия решений применяются для оценки эффективности государственной политики РФ в области развития возобновляемых источников энергии (ВИЭ) и повышения энергоэффективности. Особый акцент при оценке политики делается на достигаемые ей уровни сокращения выбросов парниковых газов. Для этого сначала предпринимается оценка потенциала страны в области энергоэффективности и развития ВИЭ. Затем анализируется законодательство страны, как уже принятое, так и планируемое, для определения спектра возможных альтернатив в области политики. Выводы затем дополняются прогнозами, взятыми из официальных государственных и международных источников, на основании чего строятся три сценария, описывающие возможные траектории развития российской энергетики в контексте демографических, экономических и климатических трендов, а также регуляторного воздействия государства на период до 2050 г. Моделирование сценариев осуществляется в среде Long-Range Energy Alternatives Planning (LEAP), а результатом являются долгосрочные прогнозы выбросов парниковых газов для российской экономики. Три портфеля политик, реализуемые в рамках сценариев, оцениваются многокритериальным методом принятия решений AMS. Наш анализ свидетельствует, что наилучшие показатели по сокращению выбросов имеет оптимистический сценарий, пессимистический — проще в реализации, а базовый — балансирует интересы вовлеченных сторон, имеющих доступ к принятию стратегических решений. Это можно рассматривать как свидетельство недостатка государственного регулирования и мотивации к вмешательству в дела энергетического сектора в целях устойчивого развития в России.

Key words: regulatory impact assessment, multi-criteria evaluation, MCDA, AMS, MAUT, SMART, long-range energy alternatives planning (LEAP), climate policy, climate change, energy policy, mitigation/adaptation, RES promotion, energy efficiency, GHG emissions.

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INTRODUCTION

The integration of renewable energy sources (RES) into Russian energy system and improving the energy efficiency of Russian economy and further transition to the low-carbon economy are among the most important topics for Russian and international policy makers. Many social, economic and technological factors have significant influence on development and evolution to the low carbon economy in Russia.

A comprehensive review of computer tools for analyzing various national energy systems was presented by Connoly *et al*. (2010). Authors considered 37 different computer packages that can be used to generate scenario prediction for development of national energy systems and finally concluded: "LEAP would be more suitable due to … lengthy scenario timeframe".

LEAP (Long-Range Energy Alternatives Planning) is an integrated modeling tool for analyzing energy consumption, transformation and production in all sectors of national economy. The Stockholm Environmental Institute and its US office in Boston developed LEAP in 1980 and now more than 5000 institutions all over the world use LEAP in their research. LEAP contains technological and environmental database (TED), which allows to input and process national economy and energy system datasets.

To compare different scenarios for development of national economy and energy system the efficient multi-criteria evaluation methods should be selected. In analysis of possible scenarios we used the multi-criteria climate change policies evaluation method AMS, combining MCDA procedures AHP, MAUT and SMART, developed by Konidari *et al.* (2007, 2008).

The rest of the paper is organised as follows. In the next two chapters we briefly survey energy-efficiency/RES potential and energy policy options currently being in the centre of discourse among Russian policy makers. Then we proceed with description of scenarios as were modeled in LEAP. Finally, we assess results of our simulation with AMS climate policy multicriteria decision-making tool.

RES POTENTIAL AND ENERGY EFFICIENCY

RES potential. Today in Russia the total installed capacity of electricity generation plants and power plants using renewable energy (without the hydroelectric power plants with installed capacity of more than 25 MW) do not exceed 2200 MW. No more than 8.5 billion kWh of electricity has been produced annually with RES, which is less than 1 percent of total production of electricity in the Russian Federation. The volume of technically available renewable energy sources in the Russian Federation is higher than 3220 Mtoe. However, due to the world energy market conditions and the modern technology restrictions only a small part of available renewable energy sources, excluding hydropower, is feasible without state subsidies. The feasible potential of renewable energy sources in Russia is around 189 Mtoe, including: geothermal sources 80 Mtoe, small hydro sources 45.6 Mtoe, biofuel sources 25.5 Mtoe, solar sources 8.75 Mtoe, wind sources 7 Mtoe, low temperature energy applications 25.5 Mtoe.

In the past support for RES has been poor in Russia. Only in November 2009, the national energy policy included a mandate for increasing RES energy generation from less than 1% to 4.5% by the year 2020 leading to additional 22 GW (Government of Russian Federation *et al.*, 2009), estimated by EBRD (2009). Russian experts in 2008 estimated that the amount of economically recoverable renewable energy is more than 270 million tons of coal equivalent (Mtce) per year, including 115 Mtce/y of geothermal energy, 65 Mtce/y of small hydropower, 35 Mtce/y of biomass, 12.5 Mtce/y of solar, 10 Mtce/y of wind and 31.5 Mtce/y of low potential heat (European Parliament, 2008). More recent estimates refer to technical resource of about 4.5 billion Mtoe with a major share attributed to solar and wind energy (EU-Russia Energy Dialogue, 2011). The corresponding economic potential is estimated at approximately 450 Mtoe (EU-Russia Energy Dialogue, 2011). These figures are mentioned also at "The Main Directions of the State Policy in the Energy Efficiency of RES Electricity for the Period up to 2020 (No.1-r)". The large RES potential is utilized to a small extent by large hydropower and wood energy use. In 2009, electricity generation based on RES (excluding large hydro power stations) was 6,75 TWh (less than 1% of total power generation) and including large hydro power plants — approximately 170 billion kWh (or almost 16% of the total energy mix) (EU-Russia Energy Dialogue, 2011).

Estimations refer to an increase of RES-based power production and consumption volume ratio (excluding hydro power stations with established capacity over 25 MW) from 0.5% in 2008 to 2.5% by 2015 and 4.5% by 2020 (EU-Russia Energy Dialogue, 2011).

One of the greatest Russian energy resources accounting in year 2009 for approximately 21% of the total generating capacity is water, although it corresponds to about 16% of production. In 2009 the country was the world's fifth largest producer of hydropower with approximately 167 TWh/yr, but only 18% of its hydropower potential was developed (EBRD, 2009).

Estimations of the total hydropower technical potential refer to about 2,400 billion kWh per year, the majority of which is based on medium and large rivers. The respective economic potential is 850 billion kWh per year (EBRD, 2009). Small hydro is the most mature RES type in the country. The potential of smaller rivers amounts to approximately 46% of total hydro energy potential (European Parliament, 2008).

Most of this potential is located in Central and Eastern Siberia and in the Far East. The Far East and Eastern Siberia combined account for more than 80% of hydropower potential, and could produce about 450–600 billion kWh per year (EBRD, 2009). The North Caucasus and the western part of the Urals also have good hydropower potential. Installed capacity amounts to 1,000 MW (European Parliament, 2008).

There is also rather high potential for wide and effective use of biomass resources since Russia has approximately 22% of the world's forests located on its territory (EBRD, 2009; European Parliament, 2008). The forest industry is an important Russian economic sector, a large potential supplier and consumer of biomass (wood waste) products. These products are only being minimally exploited. The technical potential of biomass is estimated at more than 50 Mtce.

Apart from the forestry sector, the agricultural sector is also an important source of biomass resources, but the vast majority of Russia's agricultural resources are not being used at all. An estimated 850 million liters of biofuel could be produced on this territory.

The majority of the energy produced from biomass has been used for heating purposes, and not for power generation although it is considered as most suitable solution for power production and for cogeneration of heat and electricity (European Parliament, 2008; EBRD, 2009). Approximately 40 thermal power stations use biomass (mostly waste from the wood processing industry) along with other fuels. Biomass is also used as solid fuel in certain district heating boilers being a potential niche market for biomass in the district heating systems. Installed capacity (until year 2008) accounted for 1,270 MW (European Parliament, 2008).

The technical potential of solar energy was estimated as $18.7*10^6$ GWh, with an economic potential around $1*10^5$ GWh per year (EBRD, 2009). Some areas receive more than 300 sunny days per year, and the cold temperatures also improve the efficiency of solar cells.

Russia possesses vast geothermal resources, and over 3,000 wells have been drilled to take advantage of this renewable energy type. Geothermal energy is used for heat supply and electricity production. In 2009 there were 92–129 MW of geothermal power plants operating, and about 55 MW of planned additional capacity (EBRD, 2009).

Up to 2009, Russia had only over 20 MW of wind, and new wind turbines had not been built since 2002. Estimated gross wind potential is 26,000 million tons of coal equivalent, technical potential is 2,000 Mtce, and economic potential — 10 Mtce. Approximately 30% of this economic potential is concentrated in the Far East, 16% in West Siberia and another 16% in East Siberia (EBRD, 2009).

Most of Russia's tidal power is dissipated in the Arctic regions, in particular the White Sea is considered to have a great potential. In the Mezen Bay, the difference between low tide and high tide is greater than 20 feet.

In 2007, a 1.5 MW tidal power plant by Gidro OGK began operation as a pilot project in the same bay. In case of success, the company plans 10 GW of electricity generation, and potentially to build several more tidal electro stations in other Russian bays (EBRD, 2009).

Energy efficiency. According to MED, energy efficiency in Russia is significantly lower compared to developed countries. According to information of Ministry of Energy, total energy consumption in Russia averages to about 990 millions of standard fuel tons. If Russia would implement energy saving to a scale common for European Union countries, its energy consumption would fall by 35% to 650 millions of tons of standard fuel. Energy intensity of GDP in Russia is 250% higher than world average and 250–350% higher than in developed countries (GPEE-2020). Bashmakov (2009) provides sectoral estimates of energy saving potential for Russia. The technical potential in the transportation sector is approximately 38.30 Mtoe. The potential in both heat and electricity generation will be the outcome of efficiency improvements at the generation facilities and reductions of power- and heat end-use. In electricity generation, the potential is 93 Mtoe, and in the heat supply sector — 107 Mtoe, while the potential of fuel production and transformation efficiency improvement is 41 Mtoe.

Estimations of the technical potential in electricity of the residential buildings refer to reductions of energy use for the following applications: 25.5% for space heating; 51.9% for hot water; 29.1% for cooking; 78.8% for lighting; 23.5% for appliances (refrigerators and freezers, washers, VT and video, air conditioners and other appliances).

POLICY OPTIONS FOR MITIGATION POLICIES IN RUSSIA

Analysis of relevant government documents shows that in Russia climate change mitigation and adaptation discourse almost is not reflected in official national climate strategy documents and climate-related laws, especially in terms of measurable goals and actionable plans. However Russia has very developed and complex structure of government-adopted and parliament-voted documents for RES promotion and energy efficiency, from high-level strategic documents and laws to low-level federal programs, bylaws, rules and regulations. As these policies could potentially impact GHG emissions, we interpret it as climate change policies.

Historically, first targets for increasing the use of RES and energy-efficiency were set in the following federal programmes: "Energy Efficient Economy for 2002–2005 and Period until 2010" (adopted by government on 17.11.2001); "South of Russia" (adopted by government on 8.08.2001); "Economic and Social Development of Far East and Baikal Region" (adopted on 15.04.1996) (Helio International, 2006).

The "Energy Strategy of Russia up to 2020" (Government decree No.1234-r issued on 28.08.03) was the first strategic energy program in RF. It emphasized increasing energy efficiency and implementation of proper energy pricing policy to overcome country's heavy dependence on natural gas. Its share in energy balance was about 50% during the 1990s. The "Energy Strategy 2020" proposed a wider use of coal and nuclear energy with an anticipated share in year 2020 of 21–23% and 6% respectively (Helio International, 2006).

In 2005 the "Integrated Action Plan for Implementation of Kyoto Protocol in RF" was approved by the Interdepartmental Commission. It was a detailed action plan for the period up to 2010 with quantifiable goals and workable plans as follows:

- Energy Strategy of RF until 2020 (Decree of the Russian Federation, No.1234-r, August 28, 2003);
- Federal Program "Energy Efficient Economy" for 2002–2005 and up to 2010 (Decree of the Russian Federation No.83-p, January 22, 2001);
- Draft Program of socio-economic development of the RF in the medium term (2005–2008);
- Federal Program "Modernization of Transport System of Russia (2002–2010)" (Decree of the Russian Federation, No.232-p, February 16, 2001).

As for energy efficiency and RES usage it sets the following targets:

- Energy consumption in the transport sector was expected to be restricted from 9.3 Mtce in 2004 to 10.3 Mtce in 2008 (goal was initially set in Federal Program "Modernization of Russian Transport System (2002–2010)");
- Reduction of specific fuel consumption for electricity generation in power plants of RAO "UES of Russia" was set at 8% for the period 2004–2008 (Energy Strategy of RF until 2020);
- Gas transmission and distribution losses from upstream to distribution were expected to be reduced by 47 billion m^3 for the time interval 2006–2010 (initially set by Federal Program "Energy Efficient Economy" for 2002–2005 and up to 2010);
- The share of renewable energy in total primary energy production was expected to be increased from 0,1% to 0.22%-0.3% in 2010 (initially set by Federal Program "Energy Efficient Economy" for 2002–2005 and up to 2010).

The Presidential Decree No. 889 "On some measures to improve the energy and environmental efficiency of RF economy" was approved on June 4, 2008. It is a brief document, containing only one important quantitative goal for energy efficiency: decrease of GDP energy intensity up to 2020 by 40% of 2007 level. It also contains several important president's orders to the government, with deadlines, aimed at achieving the mentioned goal.

The adoption of "The Main Directions of The State Policy in the Energy Efficiency of RES Electricity for the Period up to 2020 (No.1-r)" on January 8, 2009, became the next step, which declared the purposes and principles of RES use in RF, set quantitative targets for the share of RES electricity production/consumption in the total energy balance and defined the measures to achieve them. The document deals explicitly with the supply side of electricity balance; expands and refines goals for the Action Plan about RES by setting the following targets for RES-generated electricity (except for electricity generated by hydro power plants with power exceeding 25 MW): by 2010–1.5%, by 2015–2.5%, by 2020–4.5% share in total electricity generation.

The Climate Doctrine of RF (CD RF) (approved by Presidential Decree No.864p on December 17, 2009) is a short framework paper, describing briefly and in general terms the main notions of climate policy in RF, declaring risks and positive outcomes of global climate change for the country, wide categories of mitigation/adaptation instruments, etc. It contains not quantitative, but qualitative goals.

The "Energy Strategy for the Period of 2030", adopted in 2009, is an updated version of the previously mentioned "Energy Strategy 2020". It analyses the level of accomplishment of the previous Strategy and contains further details and expanded goals. Specifically, it points out that non-realized potential for energy intensity for Russian economy could be equal to 40% of domestic energy consumption.

The "Energy Strategy 2030" breaks down this potential into various components, namely:

- Residential buildings — 18–19%;
- Power generation, industry, transport — 13–15% each;
- Heating, services, construction — 9–10% each;
- Fuel production, gas flaring, energy government agencies — 5–6% each;
- Agriculture — 3–4%.

The "Energy Strategy 2030" sets a 56% energy intensity reduction target for 2030 (compared with year 2005). To reach this goal Russia plans to create a favourable economic environment, including progressive liberalization of energy prices on the domestic market; to promote more rational energy use, and to establish a market for energy services. New standards, tax incentives and penalties, as well as energy audits need to be adopted. The "Energy Strategy 2030" also aims to increase the energy efficiency of buildings by 50% for the time interval 2008–2030 (+10% for the period 2008–2015) by implementing new mandatory construction standards.

Finally, the state program "GPEE-2020" ("Energy saving and improving energy efficiency for a period up to 2020") was approved by the Government of Russian Federation on 27.12.2010. This program aims to decrease GDP energy intensity by 13.5%, and save up to 100 millions of standard fuel per year by 2016 and 195 millions of standard fuel per year by 2020. This goal has the following sectoral subgoals (in terms of total energy savings).

SCENARIO ASSUMPTIONS

Scenarios reflecting various paths for energy and economy development in Russia are modeled in LEAP. Long-Range Energy Alternatives Plannning (LEAP) is modeling environment, which allows to create simulation models of energy economy of certain region. It is a well established tool, used many times both by practitioners and academicians (see, for example, Konidari & Mavrakis (2007), Miranda-da-Cruz (2007), Cai, Huang, Lin, Nie & Tan (2009), Kalashnikov, Gulidov & Ognev (2011), Tao, Zhao & Changxin (2011), Zhang, Feng & Chen (2011), Shan, Xu, Zhu & Zhang (2012), Ke, Zheng, Fridley, Price & Zhou (2012)). Basic idea is as follows: we populate historical energy balances for Russia in LEAP with data from EIA; we set energy consumption structure in economy according to historical data from Rosstat; we add historical trends, reflecting changes in temperature, precipitation, country population and GDP.

We further define three scenarios: (1) business-as-usual (BAU), serving as baseline for (2) optimistic (OPT) and (3) pessimistic (PES) scenarios. Basic assumptions about economic activity, energy sec-

Table 1. Sectoral targets for energy efficiency.

Sector	Goal for 2011–2015	Goal for 2011–2020
Primary energy	334 million tons of standard fuel	1124 million tons of standard fuel
Natural Gas	108 billion m^3	330 billion m^3
Electricity	218 billion kWt/h	630 billion kWt/h
Heat	500 million Gcal	1550 million Gcal
Oil and products	5 million tons	17 million tons

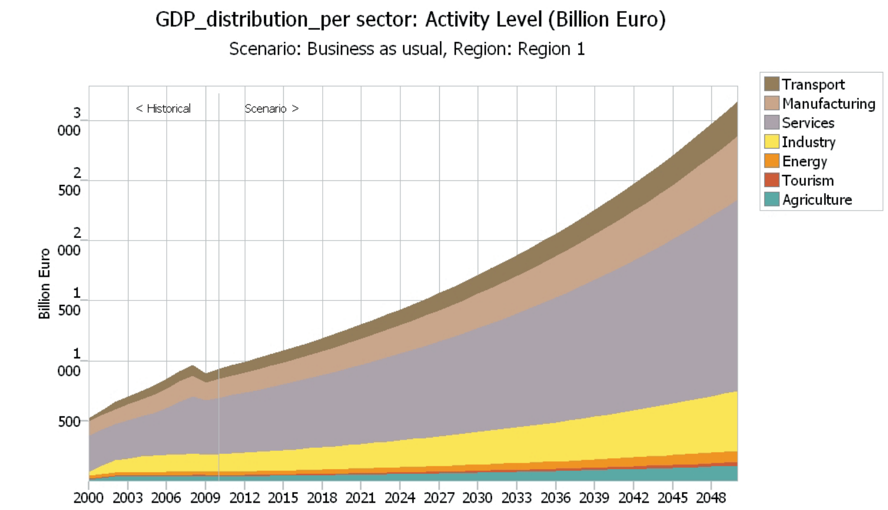

Figure 1. Sectoral distribution of output, BAU scenario.

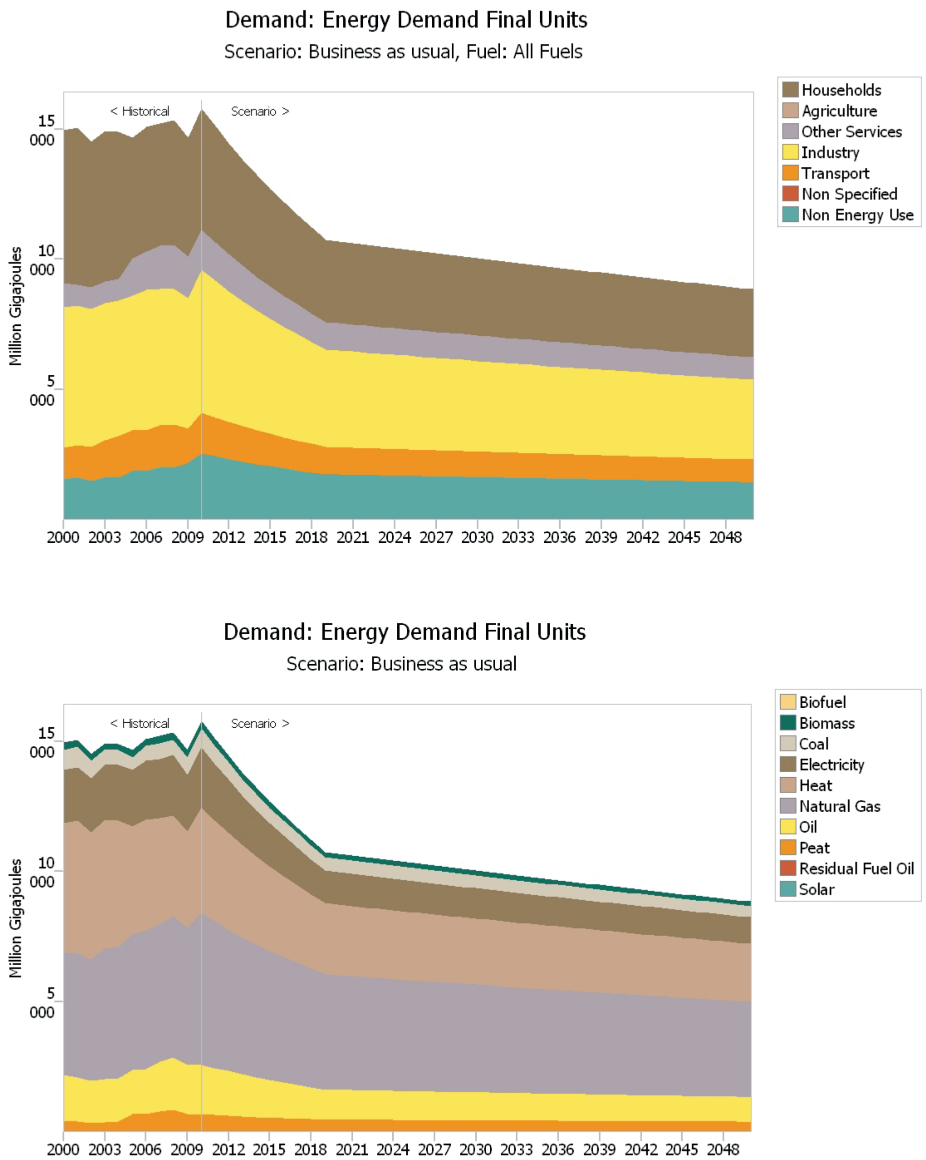

Figure 2. Total demand for energy 2011–2050 broken down to sectors (above) and sources of energy (below).

tor development paths, demography and climate for these scenarios are based on official estimates of either government or various international agencies and organisations (World Bank, IMF, UN). We use historical trends as a kind of reality check for plausibility of basic assumptions. BAU scenario contains moderate estimates of basic assumptions variables and reflects only regulations and national energy strategy, adopted and actually enacted on December 31, 2010. As for basic assumptions in OPT and PES scenarios, we used the most optimistic of all available options for OPT (the milder path for warming, better demography and GDP, innovational scenario and forced speed of development for energy sector), and the most pessimistic for PES (slower implementation of innovations, low GDP growth rate, severe climate change, bad demography). OPT and PES scenarios reflect augmented set of policies, based on what is actually discussed by government, as if it was adopted in 2011–2013 and further applied to economy and energy sector. OPT assumes that policies are implemented faster with better results, and PES — that it is implemented slower with worse results.

Using trends for economic activity detailed assumptions about sectoral structure of energy consumption (based on historical values), LEAP projects sectoral energy consumption for period 2010–2050. Using built-in technology database and energy intensity, LEAP defines GHG emissions levels for period mentioned. GHG emissions forecast is main output of LEAP model. We further use it as an input in AMS climate policy assessment procedure.

Business-as-usual (BAU) scenario. BAU-scenario is built on policy portfolio effective as of December 31, 2010, as well as scenario assumptions, grounding forecasts of government of RF and international organisations.

Population dynamics in BAU-scenario follows dynamics from scenario of "Long Term Forecast of Social-Economic Development of Russian Federation for a Period of up to 2030".

Forecast contains several scenarios for population. For BAU moderate rate forecast was selected. According to this scenario slight decrease in population is expected in 2020–2025, with subsequent recovery to 2010 level in 2030. After 2030 we assume population stabilizes and remains unchanged till 2050.

In 2008 Roshydromet published "Report on Climate Change and its Consequences in Russian Federation". Report notes beginning of a trend of temperature rise since beginning of 21 century. According to Roshydromet estimates, average temperature rise till 2050 in Russian Federation could be from 1 to 6 degrees Celsius, with probability of standard deviation quite high.

Roshydromet estimates are confirmed by several research organisations in Russia and abroad. Roshydromet/RAS Institute of Global Climate and Ecology, with participation of Hydrometcentre and other state-funded research organisations, published global scenario forecasts for climate change up to 2020, 2050, and 2080. Average temperature is estimated with ensemble of models, and deviation of predicted values could be up to 3 degrees Celsius. In our research we average historical values

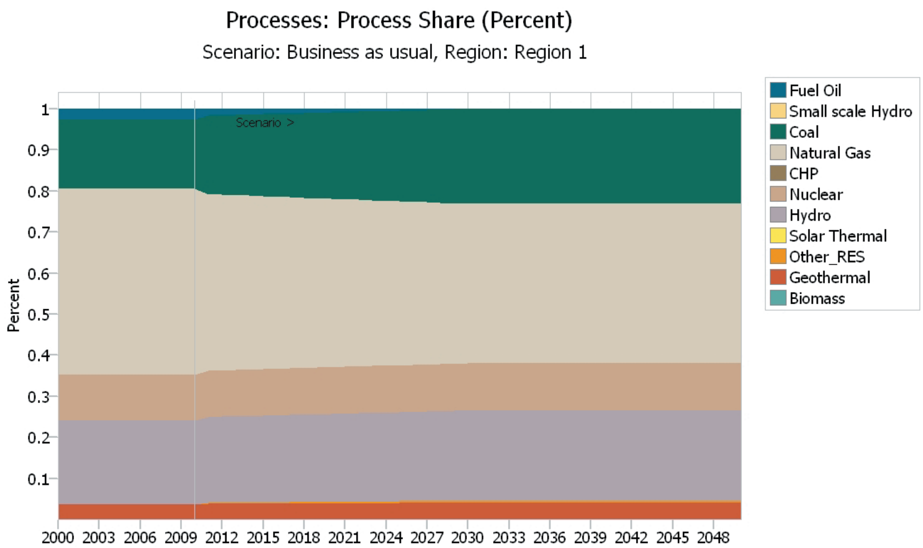

Figure 3. Historical levels and forecast for 2000–2050 of electricity generation: BAU-scenario, energy sources breakdown.

for temperature and precipitation for 1901–2009, published by World Bank, and long-term forecasts of Roshydromet and RAS. Average surface temperature for RF was about –5 degrees Celsius, according to World Bank.

Along with that, significant volatility of temperature around average level was observed, but generally during 20th century trend was horizontal, and only in 1990s and in the beginning of 21th century upward slope was observed. Taking average for 20th century as baseline, we build BAU-scenario with linear increase of average yearly temperature up to +3 degrees in 2050, which is in line with moderate forecasts of Roshydromet and RAS.

According to World Bank, long-term average level of precipitation was 460 mm. We take this level as baseline, and use RAS assumptions to model yearly change in precipitation.

Unlike scenarios for surface temperature, assuming significant changes, precipitation was assumed not to change significantly. In BAU we assume total decrease in average level of precipitation by 2 mm during all the period.

GDP as indicator of economic activity is key factor for forecasting GHG emission. In Russia this interplay is even tighter, moderated by low energy efficiency and significant role of energy sector in economy. GDP dynamics, with energy-efficiency dynamics and structural change in economy is thus key factors of energy demand and, accordingly — GHG emissions. In BAU GDP change is modeled as follows. GDP growth in 2011–2012 is assumed to be equal to historical estimates according to state statistics (in 2010–4.3%, in 2011–3.4%, in 2012–2.4%). After 2012 GDP growth rate is assumed to be equal to constant rate of 3.1%, which is in line with conservative forecast of the government of RF. We assume in BAU that this rate will persist over period of 2030–2050. Sectoral distribution of GDP will follow this dynamics too (Figure 1).

Energy efficiency. Basis for energy efficiency modeling is historical data by EIA and forecasts of state program for energy efficiency till 2020. Program has two scenarios: innovational and inertial. For BAU scenario we used inertial scenario of the program. After achieving goals of state program in 2030, energy efficiency is assumed to remain unchanged. Given that Russian economy is one of the most energy inefficient in the world, in 2030 it will still have huge potential for improving energy efficiency.

Oil and natural gas prices. Oil and gas prices are modeled according to IEA World Energy Outlook for 2010.

Energy consumption. For this section inertial scenario of Federal Target Program "Energy saving and energy efficiency till 2020" was adopted. It is assumed that after 2020 increase in energy consumption intensity will continue with twice as lower rate as during realisation of federal target program. Accounting for increase in energy efficiency total demand for energy with sectoral and energy source breakdown will look as follows (Figure 2).

Transformation: losses. According to "Energy Strategy 2030", if all measures of the strategy will be rendered, losses in heat generation will be decreased by 50% by 2030, and in electricity generation — by 2% by 2030. Assumptions of the strategy are put in BAU scenario.

Electricity generation. Historical data for primary fuel consumption for electricity generation are taken from "Energy Strategy 2030". This paper assumes achievement of definite structure of electricity generation in 2020 and 2030. In particular, it assumes increase of the share of non-fuel generation, and increase of natural gas and coal share in fuel generation. "Strategy" has no details about structure of all the other sources of electricity generation (nuclear, hydro, small RES, etc.) We model shares of these types of energy as proportional to historical structure of 2010. Change of shares toward numbers set by "Strategy 2030" is obtained by linear interpolation of shares for non-fuel, natural gas, coal and heating oil from levels of 2010. After 2030 structure of generation is assumed to remain unchanged.

OPT scenario, apart from faster realisation, assumes further improvement of structure of generation (Figure 3).

Land management policy mix was considered in the draft federal target program "Development of the reclamation of agricultural land in Russia until 2020", developed in accordance with the decision of the board of the Ministry of Agriculture of Russia No.7 on August 26, 2008, and on the basis of Article 8 of the federal law dated 29.12.2006 No.264-FZ "On the development of the agriculture sector".

RESULTS OF POLICIES SIMULATION AND ITS ASSESSMENT

The graph on Figure 4 displays greenhouse gas emissions by various sectors and types of fuel.

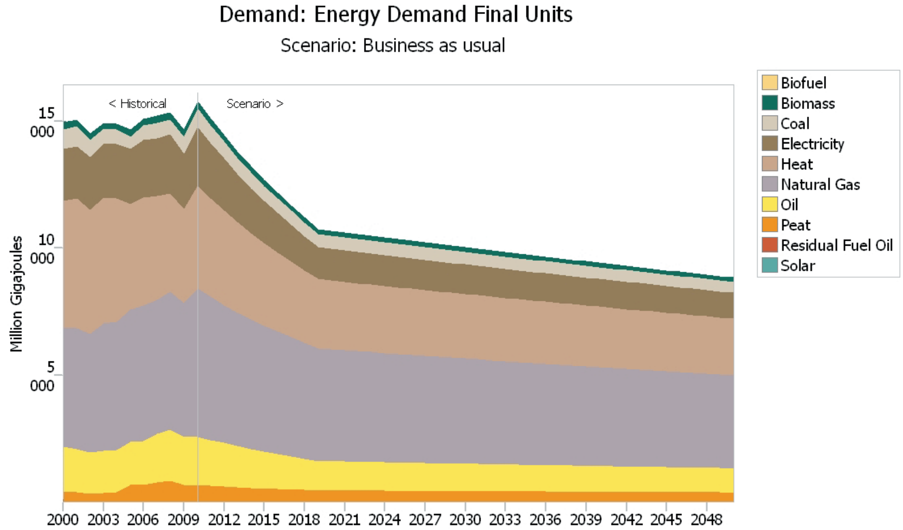

Figure 4. Historical levels and forecast for 2000–2050 of final energy demand: BAU-scenario, fuel type breakdown.

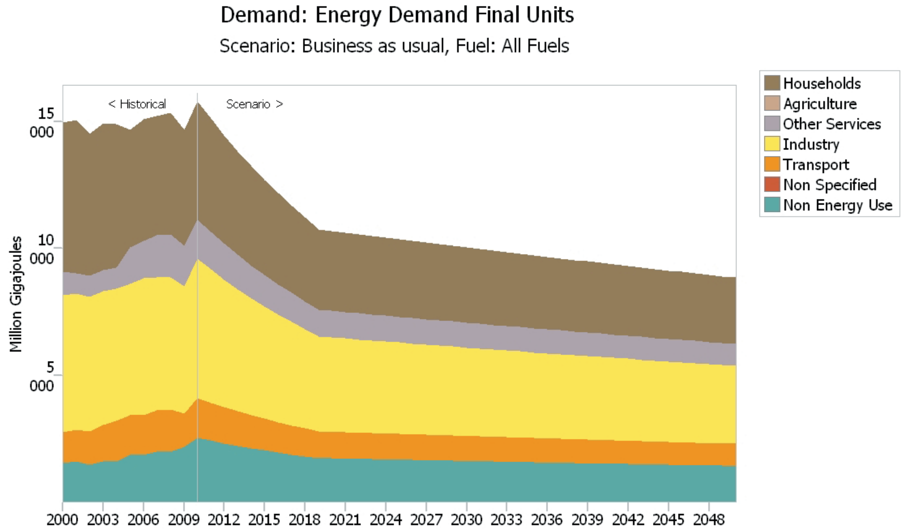

Figure 5. Historical levels and forecast for 2000–2050 of final energy demand: BAU-scenario, sectoral breakdown.

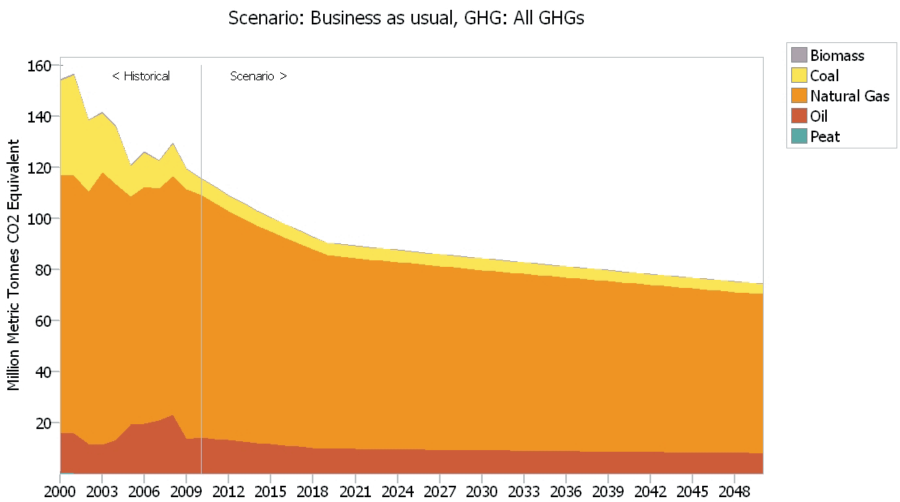

Figure 6. Historical levels and forecast for 2000–2050 of GHG emissions for households sector: BAU-scenario, fuel type breakdown.

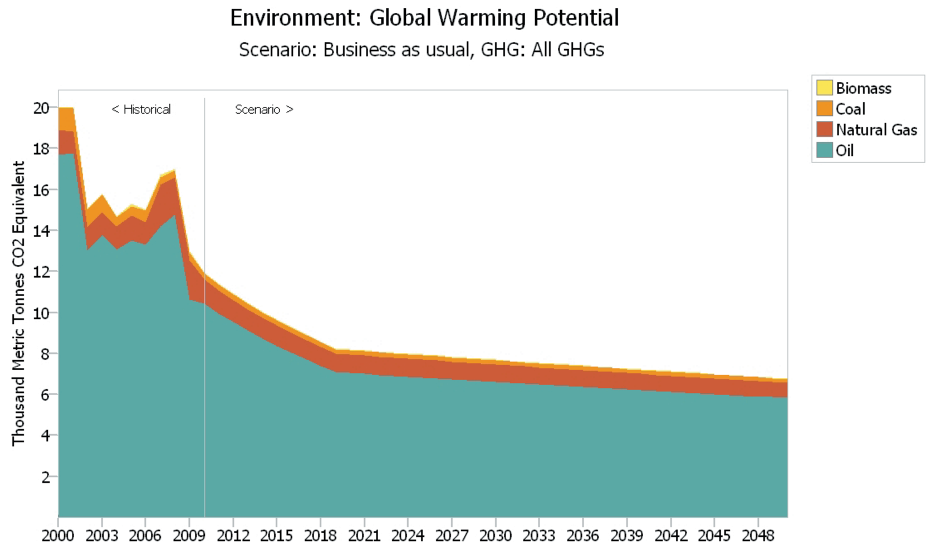

Figure 7. Historical levels and forecast for 2000–2050 of GHG emissions for agriculture sector: BAU-scenario, fuel type breakdown.

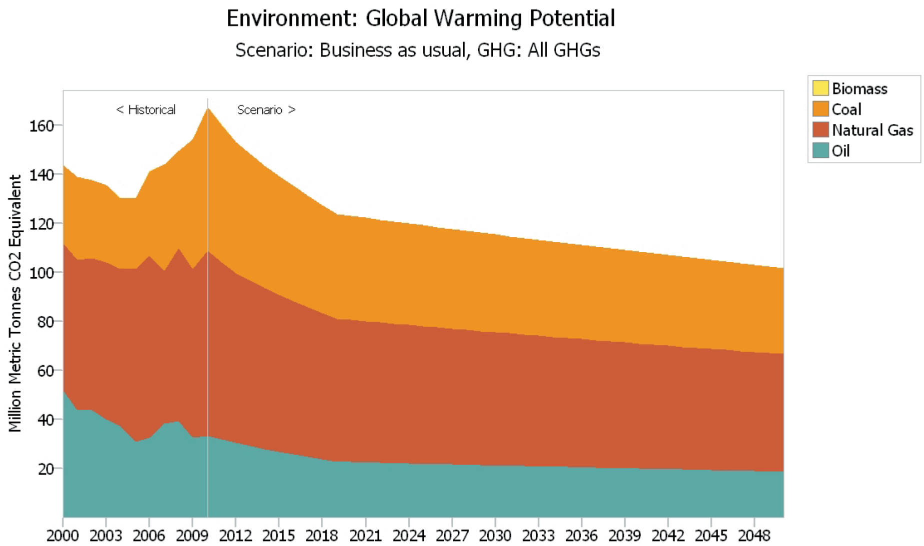

Figure 8. Historical levels and forecast for 2000–2050 of GHG emissions for industry sectors: BAU-scenario, fuel type breakdown.

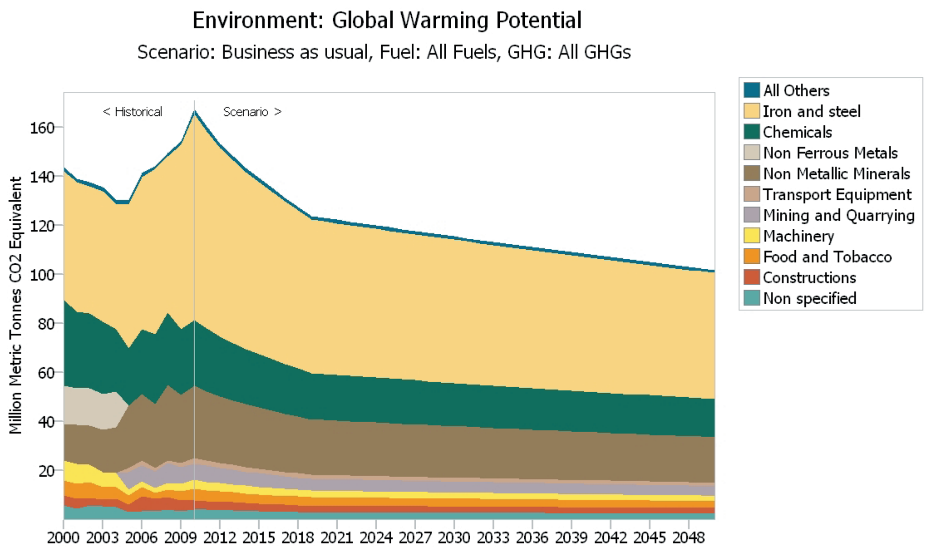

Figure 9. Historical levels and forecast for 2000–2050 of GHG emissions for industry sectors: BAU-scenario, sectoral breakdown.

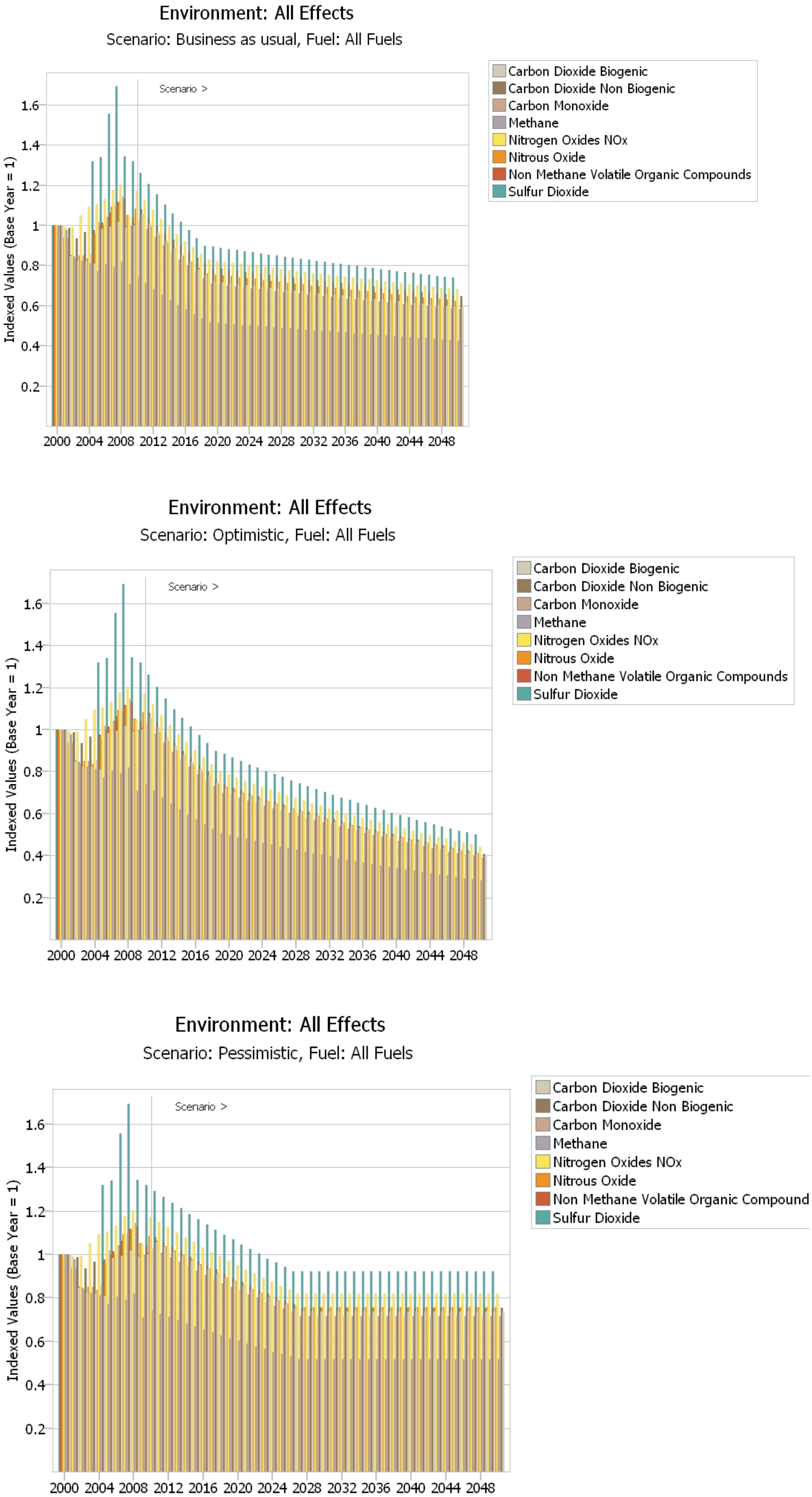

Figure 10. Historical levels and forecast for 2000–2050 of GHG emissions for services sector: BAU-, OPT-, and PES-scenario, all fuel.

AMS-ASSESSMENT OF POLICY MIXES

According to procedure proposed in Konidari (2007, 2012), we use output of LEAP simulation as input in AMS procedure to obtain final grades for various policy mixes in question. Final performance of policy mixes is assessed along following criteria: two subcriterions for environmental efficiency, assessing direct and indirect effects; several sub-criterions for political acceptability — static and dynamic cost efficiency, and competitiveness; equity; flexibility; stringency for non-compliance; and several sub-criterions for feasibility — implementation of network capacity, administrative and financial feasibility. Subcriterions of environmental efficiency are handled as follows: (1) for direct contribution to GHG emission reductions the outcome of LEAP for the total expected GHG emissions in year 2020 is used, and (2) for indirect environmental effects, the total amount of the total environmental effects provided by LEAP is used. For political acceptability criterion, there are following sub-criterions:

- Cost efficiency measures capacity of policy portfolio to achieve target parameters under financial constraints both acceptable and affordable to stakeholder entities. BAU includes the lowest volumes of regulations, many of which already have sources of financing allocated. OPT and PES require more financing, and given this, PES achieves even less reduction than BAU. Consequently, BAU is assigned the highest grade: 6, OPT: 4, PES: 2.
- Dynamic cost efficiency criterion captures opportunities, which certain policy portfolio creates to support R&D, various technologies and innovations leading to GHG emission reductions and lessening the impacts of climate change. In our case, all three scenarios — PES, OPT and BAU — contain parts promoting green (or at least "more green") technologies: energy efficiency, energy saving, smart grid, shift in energy demand, RES, etc.

PES only assumes slower and less effective rendering of such policies compared to OPT. So, both OPT and PES receive high grade for this criterion, 6 each. And BAU receives 4, as it assumes less mentioned technologies.

- Competitiveness criterion is used to assess the impact of certain policy portfolio implementation on the ability of the national economy to compete with other economies both via prices and products/services. Two common factors for economy, affecting all three scenarios, will be the price for oil and climate change. Russia is net exporter of oil, and one of minority of countries supposed to benefit from climate change. Export of oil has generally negative impact on national competitiveness when oil price is higher, both in short and long term, as it keeps ruble high and lowers motivation of industry for modernization. So PES with lower price for oil will score higher and OPT — lower given only oil factor. Climate change is assumed to be more severe in PES case, but consequences are unclear: whether Russian economy will be in position to leverage climate change challenges or will be hurt is a separate research question. Country has no particular emission reduction goals, which are regarded as lowering competitiveness, so no particular impact here. OPT scenario assumes forced implementation of energy-saving technologies and R&D support, which will contribute to higher score

Table 2. AMS results for BAU, OPT and PES scenarios.

	Weight	BAU	OPT	PES	BAU	OPT	PES
Direct contribution to GHG emission reductions	0.833	218.7458	137.9448	254.3982	262.6	165.6	305.4
Indirect environmental effects	0.167	0.8183	0.5344	0.9853	4.9	3.2	5.9
Environmental performance — A		**219.5641**	**138.4792**	**255.3835**			
Cost efficiency	0.473	2.838	1.892	0.946	6	4	2
Dynamic cost efficiency	0.183	0.732	1.098	1.098	4	6	6
Competitiveness	0.085	0.34	0.51	0.425	4	6	5
Equity	0.175	0.875	1.05	0.35	5	6	2
Flexibility	0.05	0.3	0.15	0.15	6	3	3
Stringency for non-compliance	0.034	0.204	0.136	0.136	6	4	4
Political acceptability — B		**5.289**	**4.836**	**3.105**			
Implementation network capacity	0.309	1.854	1.236	1.545	6	4	5
Administrative feasibility	0.581	3.486	2.324	2.905	6	4	5
Financial feasibility	0.11	0.77	0.44	0.55	7	4	5
Feasibility of implementation — C		**4.256**	**2.764**	**3.455**			

of OPT. Summing up, in OPT scenario economy will be more competitive due to higher energy efficiency, lower ruble rate, bigger share of knowledge economy in GDP, and (supposedly) effective use of climate change. On the opposite, competitiveness in PES will be oppressed by high prices for oil, but supported by climate change, which could have positive impact on agriculture competitiveness. The assigned grades are: BAU: 4, OPT: 6, PES: 5.

Equity criterion measures "fairness" of scenario in distributing costs and benefits associated with scenario among entities and citizens of the country. We measure intragenerational equity, social equity and sector equity. Intragenerational equity is measured as total change of GDP per capita divided by total change in emissions (MtCO2eq) per capita over 2010–2050, higher the change — lesser the score. Social equity is emission reduction per capita compared to BAU in 2050. Sector equity is standard deviation of sectoral emissions in each of three scenarios. As for intragenerational equity, PES scenario assumes slight increase in emissions per capita, so preliminary score will be negative and high. OPT and BAU have slightly different and positive change, so total score for social equity will be: OPT — 6, BAU — 5, PES — 0. For social equity, BAU will score 5, OPT — 6, and PES — 4. For sector equity, the lower standard deviation is in OPT scenario, it scores 6, with BAU slightly lower than PES (4 and 3 accordingly). For total equity criterion we will average all scores: BAU — 5, OPT — 6, PES — 2.

Flexibility criterion captures the ability of the policy instruments to offer a range of compliance options. BAU imposes minimal obligation on stakeholders and consequently offers higher flexibility. Due to the similarity of the introduced instruments in PES and OPT, equal grades are given for both. The assigned grades are: BAU — 6, OPT — 3, PES — 3.

Stringency for non-compliance and non-participation reflects the level of sanctions, imposed by regulations in each of the scenarios. Although in all scenarios regulation is quite loose, OPT and PES contain more policy instruments, and therefore should be graded lower. The grades are: BAU — 6, OPT — 4, PES — 4.

Feasibility of implementation has the following subcriterions:

- Implementation network capacity. OPT and PES scenarios contain extra policies as compared to BAU, which assume extra load for existing implementation network. The assigned grades are: BAU — 6, OPT — 4, PES — 5.
- Administrative feasibility is high for BAU, slightly lower for PES and even more lower for OPT. BAU includes well-known instruments, many of which are already being implemented. OPT and PES include more innovational instruments, with OPT including more than PES. The assigned grades are: BAU — 6, OPT — 5, PES — 4.
- For financial feasibility, only BAU has relatively high performance (scored 6). It includes policy instruments associated with federal programs, which guarantees financial recourses pre-allocated. In addition, BAU includes minimal set of policies possible. Financial requirements of OPT and PES are much higher (with OPT being the most financial resource intensive), and financial source is not defined yet. The assigned grades are: BAU — 7, OPT — 4, PES — 5.

DISCUSSION AND CONCLUSIONS

Based on the analysis of official documents and governmental programs, three scenarios of economic development of Russia until 2050 were developed. Mentioned scenarios accounted for greenhouse gas emissions from various sectors of Russian economy.

As part of the research, an econometric model in LEAP environment was built, encompassing fuel and energy balances data, as well as historical and forecasted national GDP, industry and energy structure, sectoral and total energy efficiency, and the demand for energy from sectors of economy was forecasted for up to 2050.

According to the BAU scenario, GHG emissions will be reduced by 22% by 2020 and decrease by 36% by 2050. OPT scenario will achieve reductions in GHG emissions by 28% and 60% in 2020 and 2050, respectively. Analysis of GHG emissions by sectors shows a non-monotonic behavior of the service sector GHG emissions in all scenarios, an increase in GHG emissions in 2020 from 11% to 34% in OPT and PES scenarios respectively. Calculations showed a decrease in energy intensity of GDP in 2020 to 38% for BAU and OPT, and by 22% for the PES scenarios. Modeling showed anticipatory reduction of GHG emissions by households, which reaches in 2050 52%, 72% and 48% for the BAU, OPT and PES respectively.

Final assessment according to AMS procedure could be done as follows. For criterion of environmental performance, OPT offers better grade of all scenarios; PES has the lowest, and BAU is in the middle. This could be interpreted as lack of regulation (driven, perhaps, by lack of motivation) of regulatory bodies to decrease environmental impact of Russian economy. There is definitely great leeway for improving environmental performance of the economy through implementation of new policies, many of which are currently discussed.

In line with above-mentioned considerations, and as probable explanation to it, BAU has greatest score for political acceptability, combining better cost efficiency, better flexibility and lowest sanctions level with moderate equity and competitiveness features. BAU could be regarded as *status quo*, maximizing egoistic utility of stakeholders having access to political power for reflecting their interest in policy. OPT scenario features more high-tech and green options, as it offers less natural resources-heavy options at the expense of more financial resources involved. Still it could find some political support in Russia, and it scores as the second. PES is less cost-effective both in static and dynamic aspects, it offers much less equity than OPT, and less competitiveness than BAU. Being a kind of loose-loose outcome in political aspect, it scores the third.

In addition to being the most politically acceptable, BAU has also the greatest score for feasibility of implementation. PES involves less modernization and regulatory activity, therefore it is more feasible than OPT, although less than BAU. OPT has less feasible policy mix of all three scenarios. To sum up, OPT is the most environmentally friendly, PES is easier to implement, and BAU balances interests of all stakeholders in charge.

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